SEISMIC ATTENUATION AND DISPERSION MODELS: THEORY AND VSP DATA ANALYSIS.

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Introduction

The frequency-dependent attenuation of seismic waves causes decreased resolution of seismic images with depth, and the difference in transmission losses induces amplitude variations with offset. Transmission losses may occur due to friction or fluid movement, or may result from scattering in thin-layer. Whatever the physical mechanism, they can often be conveniently described using an empirical formulation wherein the elastic moduli and propagation velocity are complex functions of frequency.

Attenuation models

Usually the attenuation coefficient is modeled with linear frequency dependence, a model referred to as the Kolsky-Futterman model. Other models have been suggested in geophysical literature. We compare eight of these models on a zero-offset vertical seismic profiling (VSP) data set: the Kolsky-Futterman, the power law, the Kjartansson, the Muller, the Azimi second, the Azimi third, the Cole-Cole, and the standard linear solid (SLS) models. For three separate depth zones we estimate velocities and Q-values for all eight models. A least-squares model-fitting algorithm gives almost the same normalized misfit for all models. Thus, none of the models can be preferred or rejected based on the given data set. Slightly better overall results are obtained for the Kolsky-Futterman model; for one depth zone, the SLS model gave the best result.

Anelastic effects in an anisotropic medium with vertical symmetry axis can be described by two complex moduli. Normalizing the complex reflection and transmission (R/T) coefficients with respect to the vertical energy flux, and expressing them as functions of the horizontal slowness instead of angles give simplified formulae. Approximate R/T coefficients derived directly in terms of the derivative of the system matrix, results in several types of approximation, depending on the choice of background medium. Numerical examples demonstrate the range of validity of these approximations, with the second-order ones being best.

The O'Doherty-Anstey formula for the P- and SV-wave transmission responses of a stack of viscoelastic VTI layers, taking into account intrinsic attenuation, anisotropy and thin layering, is of the same form as for viscoelastic isotropic layers, but the expressions are more complicated. A numerical example, using well logs, showed that, in addition to increasing the total loss, intrinsic attenuation gives a much smoother transmission response as a function of frequency and wavenumber. The influence of intrinsic anisotropy is most pronounced for larger values of horizontal slowness.

References

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